NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 4068

EFFECTS OF BLADE PLAN FORM ON FREE-SPACE OSCILLATING PRESSURES NEAR PROPELLERS AT FLIGHT MACH NUMBERS TO 0.72

By Max C. Kurbjün

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

In order to obtain information on the effects of blade plan form on the near-field noise of propellers, a series of measurements have been made of the oscillating pressures near a tapered-blade-plan-form propeller at flight Mach numbers up to 0.72. Flight Mach number, power, and engine speed were controlled in an attempt to duplicate the conditions of the flight investigation reported in NACA Technical Note 3417, where oscillating pressures were measured near a rectangular-blade-plan-form propeller.

The tapered-blade propeller produced lower sound-pressure levels than the rectangular-blade propeller for the low blade-passage harmonics (frequencies where structural considerations are important) and produced higher sound-pressure levels for the higher blade-passage harmonics (frequencies where passenger comfort is important).

The effects of flight Mach number on the oscillating pressures produced by the tapered-blade propeller are the same as were found for the rectangular-blade propeller of NACA Technical Note 3417. The lower blade-passage harmonics tend to decrease slowly with increase in flight Mach numbers up to approximately 0.5 and then to increase rapidly at higher Mach numbers. The sound-pressure levels of the higher harmonics of the propeller noise increase at a higher rate than do the lower harmonics with increase in flight number.

Relatively small changes in noise levels are observed for large changes in power settings at the design speed, flight Mach number of 0.5, of the propeller. This observation and the results of the calculations made in United Aircraft Corporation Research Department Report R-0896-2 indicate that effects other than blade loading noise, such as thickness noise, are producing noise levels of at least the same magnitude as the blade loading noise.

At speeds above a flight Mach number of 0.5, the propeller is operating above the design speed. The effect of this off-design condition in the present investigation would be to overemphasize the thickness noise relative to the blade loading noise that would normally be found in a propeller designed to operate at these higher speeds.

INTRODUCTION

In order to extend the information available on the near-field noise generated by propellers, a series of investigations have been made by using a fighter-type airplane equipped with instrumentation suitable for measuring the oscillating pressures near the propeller tips in flight.

The initial investigation (reported in ref. 1) was made to check the theory for forward-speed effects on near-field noise (ref. 2) which had not been verified at high forward speeds because of lack of suitable inflight measurements. Although it was possible to verify a few general results of the theory in the initial investigation, a need for further investigations into other parameters affecting propeller noise was indicated.

The present investigation was made primarily to obtain information on the effects of blade plan form on the oscillating pressures near the propeller at various forward speeds, power, and engine speed. The same airplane and equipment of reference 1 were used except that the rectangular-blade-plan-form propeller was changed to a tapered-blade-plan-form propeller, and measurements were made of the oscillating pressures near the propeller.

SYMBOLS

b	blade width, ft
c_l	section design lift coefficient
D	propeller diameter, ft
h	blade thickness, ft
M_∞	flight Mach number
M_t	helical tip Mach number, $\sqrt{{M_\infty}^2 + {M_R}^2}$
M_R	rotational tip Mach number
N	engine speed, rpm
P	power absorbed by propeller, hp
p	root mean square of oscillating pressure, lb/sq ft

p_o static pressure, lb/sq ft

R propeller tip radius, ft

r radius to a blade element, ft

T thrust of propeller, lb

t_o free-air temperature, ^{o}F

V airspeed, ft/sec

x longitudinal position of microphone, measured positive forward of propeller disk, ft

y radial position of microphone, measured from propeller center, ft

β section blade angle, deg

TEST EQUIPMENT

The equipment used in the present investigation was the same as that used in reference 1 except four tapered blades replaced the four rectangular blades used in reference 1. The difference in the propeller blade shapes is shown in the photographs of the two propellers mounted on the test airplane. Figure 1(a) shows the tapered blade of the present investigation, and figure 1(b) shows the rectangular blade used in reference 1. The characteristics of the two blade designs are shown in figures 2(a) and 2(b), respectively. Both propellers had a diameter of 11 feet 2 inches and were driven through a 0.479:1 engine to propeller reduction gear.

The oscillating pressure pickup used was a Western Electric condenser-type microphone modified to operate under the rapidly varying static pressures encountered in the tests. A frequency-modulation system was used to transmit the pressure signals to a ground-located station where the signals were recorded with a magnetic-tape recorder. A complete description of the pickup, transmitter, receiver, and analyzer equipment is contained in reference 3.

The microphone was installed in a boom mounted in the center gunport of the right wing. This location placed the microphone at a radial distance of 7.31 feet from the propeller axis. The boom was constructed in such a manner that the microphone could be shifted forward and backward through a distance of approximately 4 feet for adjustment before each flight. Figures 1(a) and 1(b) show the microphone-boom installation.

Before the start of the flight test program, the boom was tested in a wind tunnel to check for background noise over the anticipated flight speed range. It was found that the self-generated overall noise level of the microphone in the band width 80 to 1,000 cps was below 113 decibels. This level of self-generated random noise is considered acceptable in the measurement of sound-pressure levels as low as 100 decibels for discrete frequencies.

The response of the system used was flat within ±1 decibel between 80 and 1,000 cps.

Standard NACA recording instruments were used to record dynamic pressure, altitude, free-air temperature, engine speed, and manifold pressure.

TEST PROCEDURE

All static ground runs and flight tests were made with the microphone located at a fixed radial distance of $y = 0.655D$. Tests were made at three values of longitudinal distance $x = -0.125D$, 0, and 0.125D. Flight tests were arranged to investigate the following effects on propeller noise:

(1) Flight Mach number: At engine speeds of approximately 2,700 rpm and the manifold pressure adjusted to produce a constant power output of approximately 1,000 horsepower, flight tests were made at flight Mach numbers from approximately 0.2 to 0.7 by varying the flight attitude. Static ground runs were also made at the same power and engine speed setting.

(2) Engine (rotational Mach number): At approximately $M_\infty = 0.5$ and engine output of approximately 1,000 horsepower, runs were made at engine speeds of approximately 2,500, 2,600, 2,700, 2,800, 2,900, and 3,000 rpm.

(3) Engine power: At approximately $M_\infty = 0.5$ and engine speeds at approximately 2,700 rpm, runs were made at engine powers of approximately 0, 500, 1,000, and 1,500 horsepower.

RESULTS AND DISCUSSION

In order to show the effects of blade plan form on propeller noise, the present results, made with tapered-plan-form blades, are compared with the results obtained from the first series of tests, made with rectangular-plan-form blades, reported in reference 1. Because of the necessity of making separate flights in both sets of tests, it was impossible to repeat test conditions exactly. All test conditions are given in tables I and II for the present investigation and the investigation of reference 1, respectively. The data used for the figures in the present report are indicated in the tables. In the discussion, the small differences in test conditions are disregarded.

In this report the root-mean-square oscillating pressures are given in decibels; the relation between decibels and pressures in pounds per square foot is as follows:

$$\text{Decibels} = 20 \log \frac{480p}{0.0002}$$

The effects of propeller blade plan form are shown as a series of figures comparing noise emitted from the two propellers tested with changes in operating parameters of Mach number, engine speed (rotational Mach number), and power.

Effects of Flight Mach Number

The effects of flight Mach number at the three axial microphone locations are shown in figure 3. A trend is shown for the lower blade-passage harmonics of both blade designs to decrease slowly in sound-pressure level as the flight Mach number increases to approximately 0.5 and to increase rapidly with further increase in flight Mach number. For the lower blade-passage harmonics the tapered-blade design shows lower sound-pressure levels than the rectangular-blade design.

The higher harmonics show a slight increase in sound-pressure level for both blade designs up to approximately $M_\infty = 0.5$ with rapid increases for higher flight Mach numbers. Above $M_\infty = 0.5$ the tapered-blade design shows a more rapid increase in sound-pressure levels with Mach number than the rectangular-blade design. This trend, which is more pronounced for the higher harmonics, produces higher sound-pressure levels in the higher harmonic range for the tapered-blade design than for the rectangular-blade design.

Effects of Engine Speed (Rotational Mach Number)

The effects of changing the engine speed (rotational Mach number) on the sound-pressure levels of the tapered-blade design at a constant forward Mach number and power are shown in figure 4. The increase in oscillating pressures with rotational Mach number for the first harmonic is relatively small; whereas, the increase for the higher harmonics becomes increasingly greater.

Figures 5(a) and 5(b) show the similarity of the effects of flight Mach number and rotational Mach number. Data for figure 5(a) were obtained at a flight Mach number of approximately 0.5 and an engine speed of 2,900 rpm. Data for figure 5(b) were obtained at a flight Mach number of approximately 0.6 and an engine speed of 2,700 rpm. The resultant Mach number for both conditions is approximately 0.95. The similarity of the two figures shows that in the range of the two conditions the effects of increases in flight Mach number are the same as increases in rotational speeds.

Effects of Engine Power

The effects of engine power delivered to the tapered-blade propeller on the noise emitted from the propeller are shown in figure 6 for the three axial microphone locations. These tests were not conducted on the rectangular-blade propeller. The relatively small change in noise level with large changes in power displayed by the tapered-blade propeller seems to indicate that the propeller is also producing thickness noise of at least the same order of magnitude as the loading noise.

The power delivered to the propeller is seen to affect the noise emitted by the order of 6 decibels. This order of magnitude is far less than would be expected by consideration of only the blade loading noise as done in reference 2. However, calculations of thickness noise made in reference 4 show that the magnitude of the thickness noise, for the rectangular-blade propeller of reference 1 operating under the same flight conditions shown for figure 6, are within 6 decibels of the blade loading noise.

It should be noted that the propellers used in the present investigation and the one of reference 1 are designed for a flight Mach number of 0.5. At speeds above the design condition the outer portions of the blades tend to unload. Also, for a given horsepower input, the average thrust necessarily drops in proportion to the forward-speed increase. The combination of these two factors and the near location of the microphone to the tip would cause the results found in the present investigation and reference 1 to overemphasize the thickness noise in comparison to the loading noise in the higher speed conditions. This may be, in part, the reason that the results of the present investigation and those of reference 1 do not completely substantiate the theory of reference 2.

CONCLUDING REMARKS

In order to obtain information on the effects of blade plan form on the near-field noise of propellers, a series of measurements were made of the oscillating pressures in the vicinity of a propeller with tapered-blade plan form at flight Mach numbers up to 0.72. The measurements are compared with the results of the tests conducted with the rectangular-blade-plan-form propeller reported in NACA Technical Note 3417. Measurements were made at a single radial station and at positions ahead of, in the plane of, and behind the propeller disk. The present tests were conducted at various forward speeds, engine speeds, and power settings to investigate the effects of these parameters.

The tapered-blade-plan-form propeller produced lower sound-pressure levels than the rectangular-blade-plan-form propeller for the low blade-passage harmonics (the frequencies where structural considerations are important) and produced higher sound-pressure levels for the higher blade-passage harmonics (frequencies where passenger comfort is important).

The effects of flight Mach number on the oscillating pressures produced by the tapered-blade propeller are the same as were found for the rectangular-blade propeller of NACA Technical Note 3417. The lower blade-passage harmonics tend to decrease slowly with increase in flight Mach numbers up to a Mach number of approximately 0.5 and then to increase rapidly at higher Mach numbers. The sound-pressure levels of the higher harmonics of the propeller noise increase at a higher rate than those for the lower harmonics with increase in flight Mach number.

The relatively small change in the noise level with large changes in power settings at the design speed of the propeller indicates that the propeller is also producing thickness noise of at least the same order of magnitude as the loading noise. This is in agreement with the calculation made in United Aircraft Corporation Research Department Report R-0896-2 for the rectangular-blade-design propeller of NACA Technical Note 3417.

At flight Mach numbers above 0.5, the results of the present investigation and of NACA Technical Note 3417 are for propellers operating above the design speed condition. The effect of this off-design condition would be to overemphasize the thickness noise relative to the loading noise that would normally be found in a propeller designed to operate at these higher speeds.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 15, 1957.

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3. Mace, William D., Haney, Francis J., and Brummer, Edmund A.: Instrumentation for Measurement of Free-Space Sound Pressures in the Immediate Vicinity of a Propeller in Flight. NACA TN 3534, 1956.

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TABLE I.- RESULTS WITH TAPERED-BLADE-PLAN-FORM PROPELLERS

[y = 0.655D]

Test conditions														Sound-pressure level, db (Reference pressure level, 0.0002 dynes/cm²)									
														Order of harmonic									
Flight	Test	Figure	x	T, lb	V, ft/sec	p_0, lb/sq ft	t_0, °F	P, hp	N, rpm	M_∞	M_R	M_t	Blade-passage frequency, cps	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th
	1	------	0.125D	2,800	0	2,110	81	1,030	2,693	0	0.66	0.66	86.0	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
	2	------	.104D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0										
	3	------	.089D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0										
	4	------	.075D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	128.6	122.6	116.7	110.0	109.3	108.7				
	5	------	.060D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	128.9	121.5	116.5	112.7						
	6	------	.045D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	128.7	122.3	117.1	112.9						
	7	------	.030D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	127.2	122.0	116.3	111.3	109.9					
	8	------	.015D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	127.5	121.0	116.3	111.3	108.0					
	9	3	0	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	127.1	120.3	115.6							
	10	------	-.015D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	131.9	124.5	120.5	114.5						
	11	------	-.030D	2,800	0	2,110	81	1,030	2,693	0	.66	.66	86.0	126.7	120.3	114.9	109.9						
	12	------	-.045D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	126.5	118.1	115.1	109.2						
	13	------	-.060D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	126.7	120.5	115.1	109.5						
	14	------	-.075D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	126.8	118.0	116.0	108.5						
Ground	15	------	-.089D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6										
	16	------	-.104D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	126.5	116.1	116.3			109.7				
	17	3	-.125D	2,800	0	2,110	81	1,030	2,681	0	.66	.66	85.6	126.1	115.5	116.8							
	18	------	.125D	1,490	0	2,110	81	570	2,418	0	.59	.59	77.2	126.1	116.2	110.8							
	19	------	.125D	1,850	0	2,110	81	710	2,568	0	.63	.63	82.0	128.0	119.8	113.8							
	20	3	.125D	2,500	0	2,110	81	960	2,681	0	.66	.66	85.6	128.6	120.8	116.0	110.0						
	21	------	.125D	3,100	0	2,110	81	1,200	2,919	0	.72	.72	93.2	130.5	124.7	120.5	115.0						
	22	------	0	1,490	0	2,110	81	570	2,405	0	.59	.59	76.8	122.1	113.2	109.5							
	23	------	0	1,850	0	2,110	81	710	2,593	0	.64	.64	82.8	125.0	117.0	113.0	108.0						
	24	------	0	2,500	0	2,110	81	960	2,693	0	.66	.66	86.0	127.8	121.5	117.7	112.0	110.5					
	25	------	0	3,100	0	2,110	81	1,200	2,944	0	.72	.72	94.0	129.9	123.9	120.1	115.5	113.5					
	26	------	-.125D	1,490	0	2,110	81	570	2,380	0	.58	.58	76.0	119.9	109.0	110.0	104.7	104.5					
	27	------	-.125D	1,850	0	2,110	81	710	2,596	0	.64	.64	82.9	123.5	113.5	113.5							
	28	------	-.125D	2,500	0	2,110	81	960	2,768	0	.68	.68	88.4	127.2	120.0	117.5	109.0						
	29	------	-.125D	3,100	0	2,110	81	1,200	2,937	0	.72	.72	93.8	129.9	123.0	120.0	113.5						
	1	3	-0.125D	2,040	235	965	13	1,030	2,699	0.22	.71	.74	86.2	123.5	117.5	112.0	107.8	104.0	106.0				
	2	3	-.125D	1,275	375	975	15	1,030	2,687	.35	.71	.79	85.8	118.3	111.7	107.5	107.0	102.0					
	3	------	-.125D	1,240	385	945	14	1,030	2,699	.36	.71	.79	86.2	120.7	113.7	-----	Noisy	-----					
	4	4	-.125D	908	524	988	15	1,030	2,490	.49	.63	.82	79.5	118.3	113.5	108.2	109.3	105.5					
	5	4	-.125D	914	530	970	14	1,050	2,584	.50	.68	.84	82.5	117.7	112.7	110.1	109.7	106.5					
	6	3,4	-.125D	914	530	955	14	1,050	2,687	.50	.71	.86	85.8	117.2	114.2	111.5							
	7	4	-.125D	914	530	948	14	1,050	2,787	.50	.73	.88	89.0	117.9	115.3	113.7	113.5						
	8	4,5(a)	-.125D	924	524	955	14	1,050	2,847	.49	.74	.89	90.9	118.0	116.0	117.0	116.2	115.0					
3	9	4	-.125D	924	524	955	13	1,050	2,951	.49	.74	.89	94.3	119.0	118.2	119.5	118.8	116.7	114.9	111.9	109.5	108.0	
	10	6	-.125D	0	526	1,005	17	0	2,677	.49	.70	.85	85.5	118.1	114.9	111.8	108.3						
	11	6	-.125D	545	526	1,014	17	600	2,687	.49	.70	.86	85.8		112.4	110.9	108.8	105.9					
	12	6	-.125D	800	526	1,000	16	900	2,690	.49	.70	.86	85.9		111.5	109.5	108.5	110.5					
	13	6	-.125D	1,280	526	990	15	1,400	2,701	.49	.71	.86	86.3	119.9	115.7	112.5	110.5	106.5	105.3				
	14	3,5(b)	-.125D	743	652	970	15	1,040	2,697	.59	.71	.92	86.1	119.0	116.7	115.1	113.0	110.0	108.5	106.0			
	15	3	-.125D	573	775	1,040	20	1,040	2,672	.72	.70	1.00	85.3	132.1	134.0	133.2	132.0	129.7	127.2	124.0	121.0	120.5	
	16	------	-.125D	568	785	1,010	20	1,040	2,682	.72	.70	1.00	85.6	132.7	135.5	134.5	132.8	130.0	127.3	124.0			
	17	------	-.125D	698	785	960	26	1,280	2,926	.72	.77	1.05	93.5	133.8	136.9	136.7	134.5	133.5	127.8	123.8	121.2	118.0	117.0

[a]Lost due to infiltration of extraneous noise at receiving station.

TABLE I.- RESULTS WITH TAPERED-BLADE-PLAN-FORM PROPELLERS - Concluded

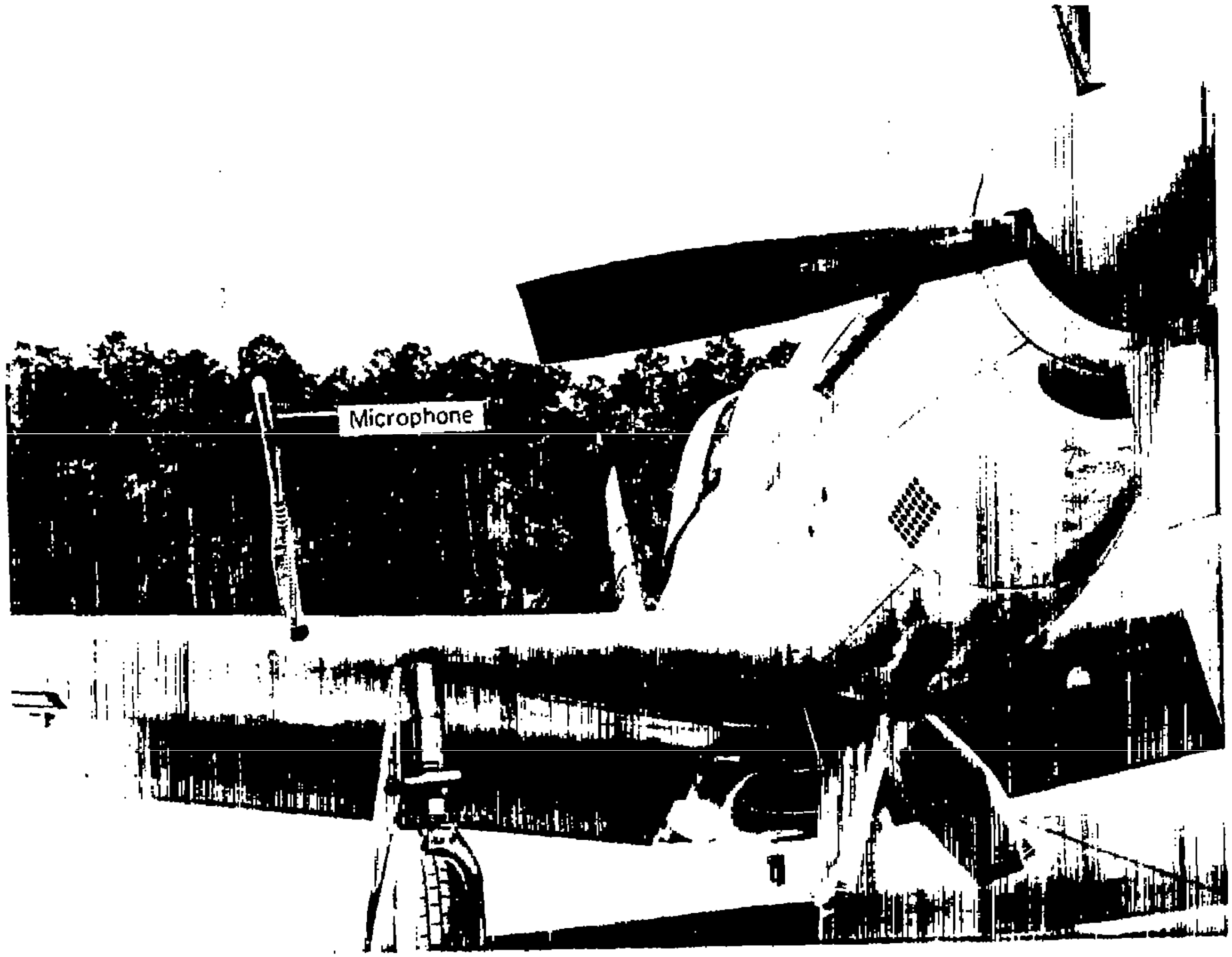
[y = 0.655D]

Test condition														Sound-pressure level, db (Reference pressure level, 0.0002 dynes/cm²)									
														Order of harmonic									
Flight	Test	Figure	x	T, lb	V, ft/sec	p_0, lb/sq ft	t_0, °F	P, hp	N, rpm	M_∞	M_R	M_t	Blade-passage frequency, cps	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th
6	1	3	0	2,050	231	958	-1	1,020	2,677	0.22	0.71	0.75	85.5	124.8	121.1	117.6	113.8	109.5	106.5	102.0			
	2	------	0	2,030	235	980	4	1,020	2,677	.22	.71	.74	85.5	123.8	119.6	115.7	110.0	108.2	106.4	104.0			
	3	3	0	1,100	349	970	4	1,020	2,677	.33	.71	.78	85.5	123.6	119.5	116.1	112.8	109.0					
	4	4	0	908	516	940	0	1,020	2,495	.49	.66	.82	79.6	121.6	118.3	114.9	111.9	109.7					
	5	4	0	915	516	940	0	1,050	2,577	.49	.68	.84	82.3	122.5	120.1	117.3	114.6	110.3	108.7	105.0			
	6	3,4	0	910	521	920	-2	1,040	2,681	.50	.71	.87	85.6	123.3	121.5	120.1	118.2	115.0	112.5	108.5	106.0		
	7	4	0	915	525	900	-4	1,050	2,778	.50	.74	.89	88.7	124.3	123.3	122.5	121.3	119.1	116.9	114.1	110.5	108.0	105.0
	8	4,5(a)	0	920	522	880	-6	1,050	2,878	.50	.77	.91	91.9	125.4	126.3	126.3	126.2	125.7	124.4	122.4	119.9	117.3	114.0
	9	4	0	945	507	860	-8	1,050	2,940	.49	.79	.93	93.9	125.9	127.6	128.3	128.1	127.2	125.0	123.3	120.7	117.5	
	10	6	0	0	528	950	3	0	2,712	.50	.72	.88	86.6	120.3	120.9	119.7	117.3	114.7	111.5	107.1			
	11	6	0	540	532	1,010	8	600	2,706	.50	.71	.87	86.4	120.7	120.5	119.3	117.0	113.6	116.8	108.5	105.0	103.0	
	12	6	0	870	525	995	6	1,000	2,702	.50	.71	.87	86.3	121.6	120.6	119.3	116.8	114.1	111.4	108.0	105.5	100.0	
	13	3,5(b)	0	723	650	1,040	12	1,040	2,702	.61	.71	.94	86.3	126.9	127.7	127.7	126.8	125.4	123.0	120.5	117.9	114.9	113.0
	14	3	0	652	702	850	-5	1,040	2,702	.67	.72	.99	86.3	131.2	134.4	135.2	134.1	131.2	127.0	121.8	119.8	119.8	118.8
	15	------	0	808	707	860	0	1,300	2,928	.67	.78	1.02	93.5	134.8	139.5	140.3	138.0	131.9	120.0	125.5	125.9	123.4	119.0
7	1	3	0.125D	2,170	222	965	3	1,030	2,702	.21	.72	.75	86.3	125.7	121.3	115.8	112.7	108.2	102.5				
	2	3	.125D	1,295	370	960	3	1,030	2,702	.35	.72	.80	86.3	124.7	120.7	116.9	112.7	110.9					
	3	4	.125D	900	526	970	4	1,030	2,493	.50	.66	.83	79.6	123.5	119.4	114.6	109.1	104.5	103.5	102.5			
	4	4	.125D	912	528	960	3	1,000	2,587	.50	.69	.85	82.6	124.3	118.1	116.7	112.9	108.0	103.3				
	5	3,4	.125D	920	528	955	2	1,050	2,690	.50	.71	.87	85.9	125.3	122.5	119.3	115.0	111.5	105.0				
	6	4	.125D	910	532	940	1	1,050	2,778	.50	.75	.92	88.7	125.9	123.7	121.5	118.8	115.6	110.9	107.9	104.0	102.5	
	7	4,5(a)	.125D	912	527	988	-1	1,050	2,881	.50	.77	.92	92.0	126.6	124.0	122.8	120.1	117.0	113.7	111.0	108.0	106.0	
	8	4	.125D	878	520	915	-3	1,050	2,953	.50	.79	.93	94.3	127.3	127.5	127.0	125.8	123.7	120.7	117.5	114.5	111.5	110.0
	9	6	.125D	0	517	960	3	0	2,677	.49	.71	.86	85.5	119.5	119.3	116.7	112.9	109.7	107.3				
	10	6	.125D	490	537	1,010	7	550	2,671	.51	.70	.87	85.3	122.2	120.2	117.6	113.6	109.8	106.0	103.5			
	11	6	.125D	775	532	1,025	9	900	2,728	.50	.72	.87	87.1	123.4	120.7	117.5	113.5	109.9	105.6	103.5			
	12	3,5(b)	.125D	730	640	1,045	12	1,040	2,705	.60	.71	.94	86.3	128.2	126.3	125.5	122.9	119.7	116.2	111.7	107.0		
	13	3	.125D	644	704	900	10	1,050	2,692	.66	.71	.97	84.7	131.5	135.0	132.0	129.7	125.6	126.9	119.3	118.3	116.5	114.5
	14	------	.125D	643	698	950	5	1,020	2,702	.66	.71	.97	86.3	131.0	132.4	131.6	129.5	125.8	120.9	118.2	119.2	115.5	113.5
	15	------	.125D	800	698	950	5	1,270	2,953	.66	.78	1.02	94.3	135.1	138.0	136.5	132.2	124.6	123.5	123.8	122.5	119.4	117.5

TABLE II.- RESULTS WITH RECTANGULAR-BLADE-PLAN-FORM PROPELLERS

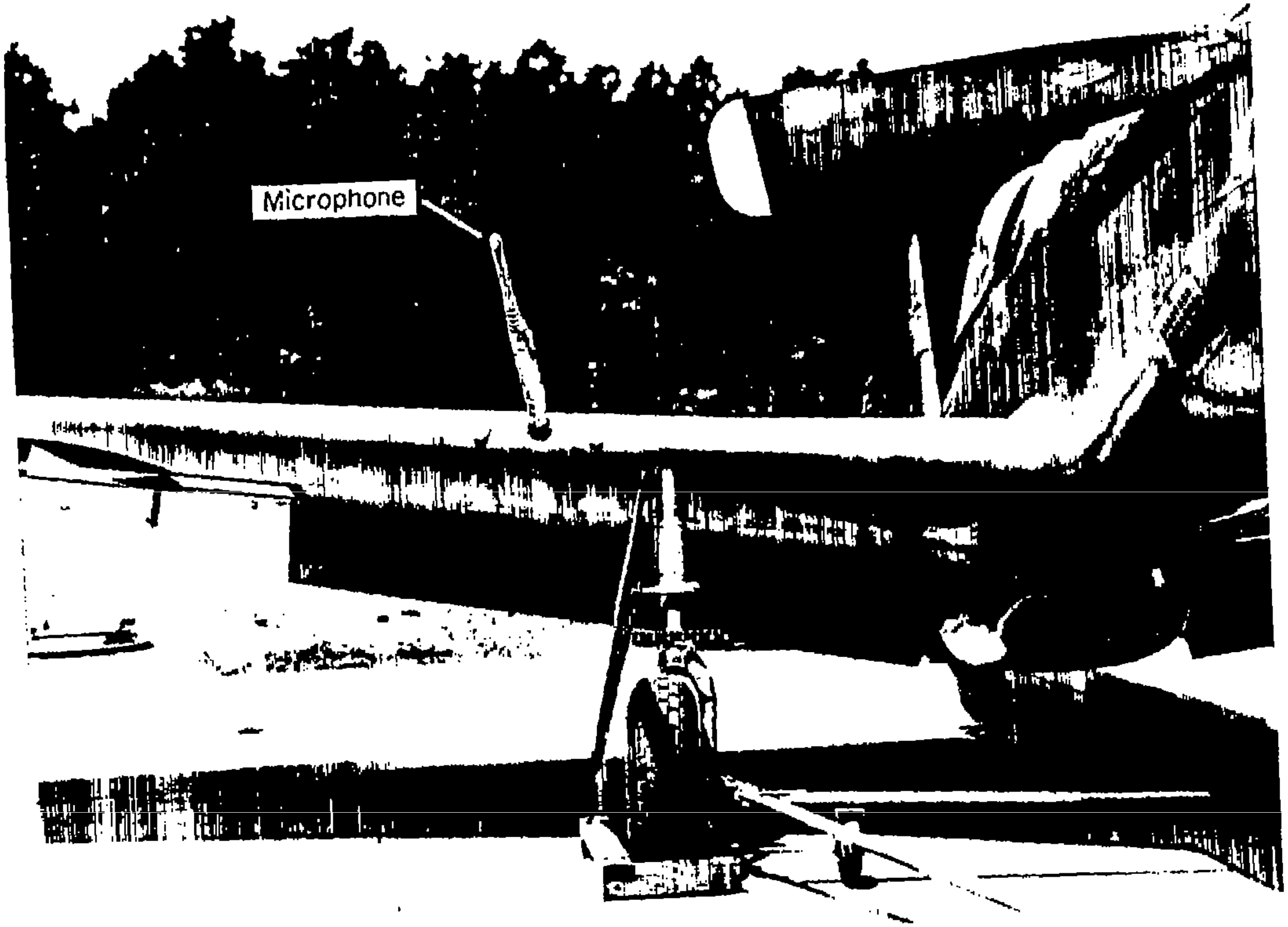
[y = 0.655D]

Test conditions														Sound-pressure level, db (Reference pressure level, 0.0002 dynes/cm^2)									
														Order of harmonics									
Flight	Test	Figure	x	T, lb	V, ft/sec	p_o, lb/sq ft	t_o, °F	P, hp	N, rpm	M_∞	M_R	M_t	Blade-passage frequency, cps	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th
Ground	1	3	0.125D	2,800	0	------	69	1,050	2,705	0	0.67	0.67	86.4	131.5	125.5	118.0	111.0	112.0					
	3	3	0	2,800	0	------	69	1,050	2,700	0	.67	.67	86.2	129.5	123.0	118.5	113.0						
	5	3	-.125D	2,800	0	------	69	1,050	2,700	0	.67	.67	86.2	129.0	120.0	119.0	108.0						
1	1	3	-0.125D	2,160	222	960	5	1,050	2,697	0.21	0.72	0.73	86.2	125.0	119.0	113.5	109.0						
	2	3	-.125D	1,340	359	962	0	1,040	2,715	.34	.73	.80	86.7	123.5	117.8	112.5	109.5	107.0					
2	3	------	-0.125D	915	520	947	-7	1,050	2,497	0.50	0.67	0.84	79.5	120.5	115.6	109.5	107.5						
	4	------	-.125D	942	513	969	-11	1,050	2,597	.49	.70	.86	82.9	120.5	116.0	112.0	109.5						
	5	3	-.125D	946	522	961	-5	1,060	2,712	.49	.72	.88	86.6	121.5	116.5	112.5	108.0						
	7	5(a)	-.125D	960	515	961	-6	1,070	2,893	.49	.75	.92	92.3	122.5	118.5	116.0	112.5	107.5	104.5				
	8	------	-.125D	965	516	966	-6	1,075	2,940	.49	.78	.95	94.0	122.0	120.0	118.0	114.5	110.4	106.5				
	9	3,5(b)	-.125D	756	628	980	-6	1,060	2,717	.60	.73	.94	86.6	124.5	121.5	118.0	112.5						
	10	3	-.125D	585	727	1,075	0	1,050	2,730	.72	.72	1.02	87.2	135.0	136.5	134.0	131.0	126.0	121.5				
	11	------	-.125D	738	747	1,040	-3	1,280	2,910	.71	.79	1.07	95.0	137.0	139.0	137.0	133.0	126.5					
3	1A	5	0	1,830	270	947	9	1,048	2,710	0.25	0.71	0.76	86.6	129.5	125.0	120.0	115.5						
	2A	5	0	1,310	374	945	9	1,048	2,710	.35	.72	.80	86.6	128.0	124.0	119.5	114.5						
	3	3	0	955	525	951	10	1,080	2,705	.49	.71	.87	86.4	126.5	123.5	120.5	115.5	111.0					
	4	5(a)	0	1,550	524	955	10	1,530	2,945	.49	.77	.92	94.0	131.0	130.0	128.0	125.0	121.5	117.0	113.0			
	5	3,5(b)	0	774	.635	983	11	1,080	2,700	.59	.71	.93	86.2	129.0	128.0	126.0	122.5	117.5	112.0	107.5			
	6	3	0	574	767	1,000	15	1,030	2,665	.72	.71	1.01	85.8	138.5	142.0	141.5	138.0	131.0	124.5	128.5	127.0	123.5	121.5
	7	------	0	710	768	1,050	18	1,270	2,910	.72	.76	1.04	92.9	143.5	146.0	142.0	129.5	128.5	129.5	125.0			
4	1	3	0.125D	2,180	226	952	4	1,040	2,695	0.21	0.71	0.74	86.0	129.5	124.5	120.0	115.0						
	2	3	.125D	1,300	369	945	5	1,035	2,700	.35	.71	.78	86.2	128.0	125.0	119.0	113.5						
	3	3	.125D	950	531	968	5	1,070	2,690	.50	.71	.87	85.8	128.5	125.5	122.0	117.5	114.0					
	4	5(a)	.125D	1,360	517	966	5	1,530	2,945	.49	.78	.92	94.0	131.0	130.5	129.0	126.5	123.0	119.5	114.5			
	5	3,5(b)	.125D	762	629	985	7	1,060	2,682	.59	.71	.92	85.6	130.5	129.5	127.0	123.5	119.5	115.0				
	6	3	.125D	606	761	940	6	1,080	2,665	.72	.71	1.01	85.0	138.0	139.5	135.1	124.0	126.0	126.5	122.0	120.5	119.0	
	7	------	.125D	890	744	940	5	1,550	2,920	.70	.77	1.04	93.2	142.5	143.5	133.5	132.5	133.0	121.0	128.0	123.5	124.5	123.0



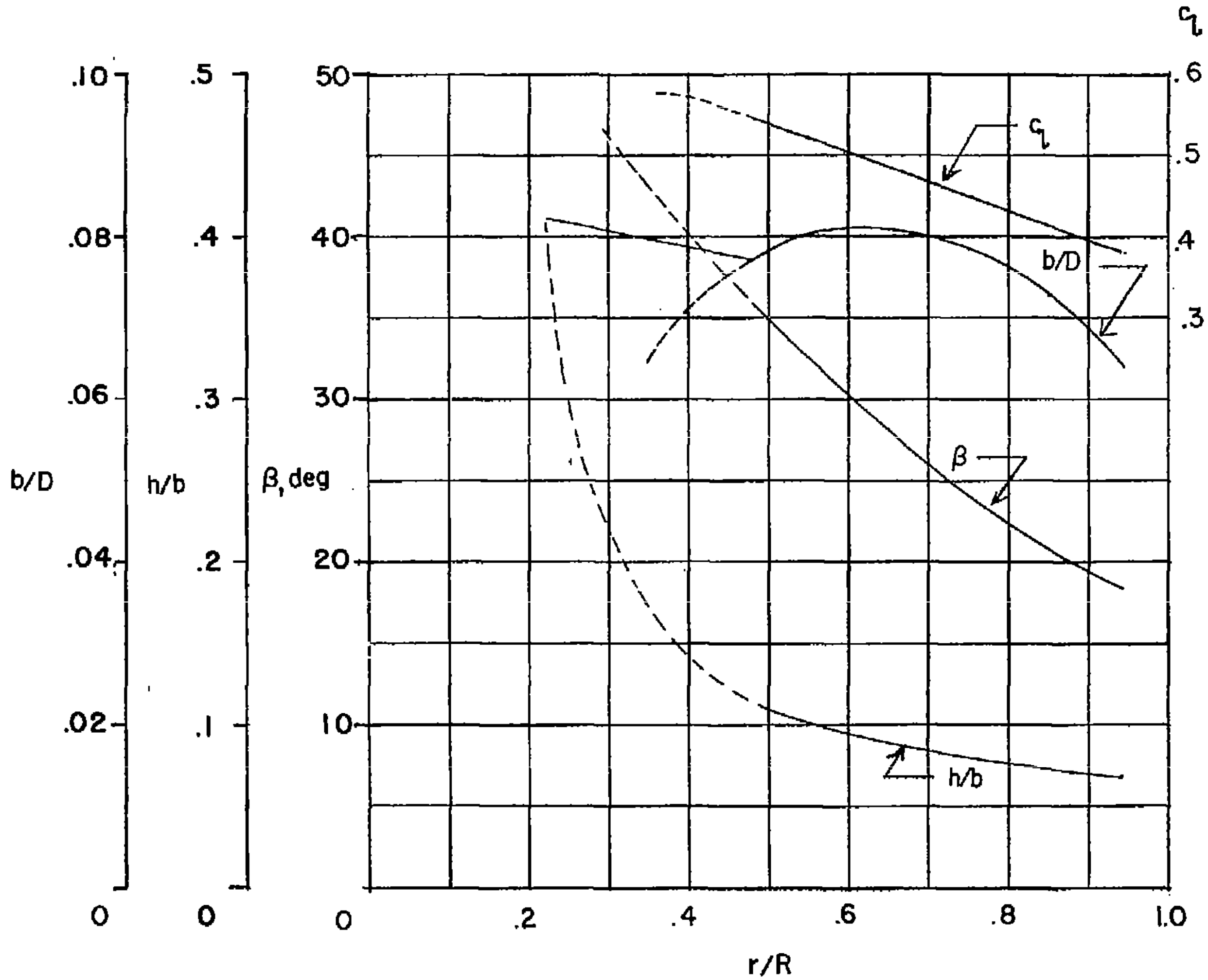
(a) Tapered-blade plan form. L-92782.1

Figure 1.- Front view of the microphone installation showing the propeller-blade shape.



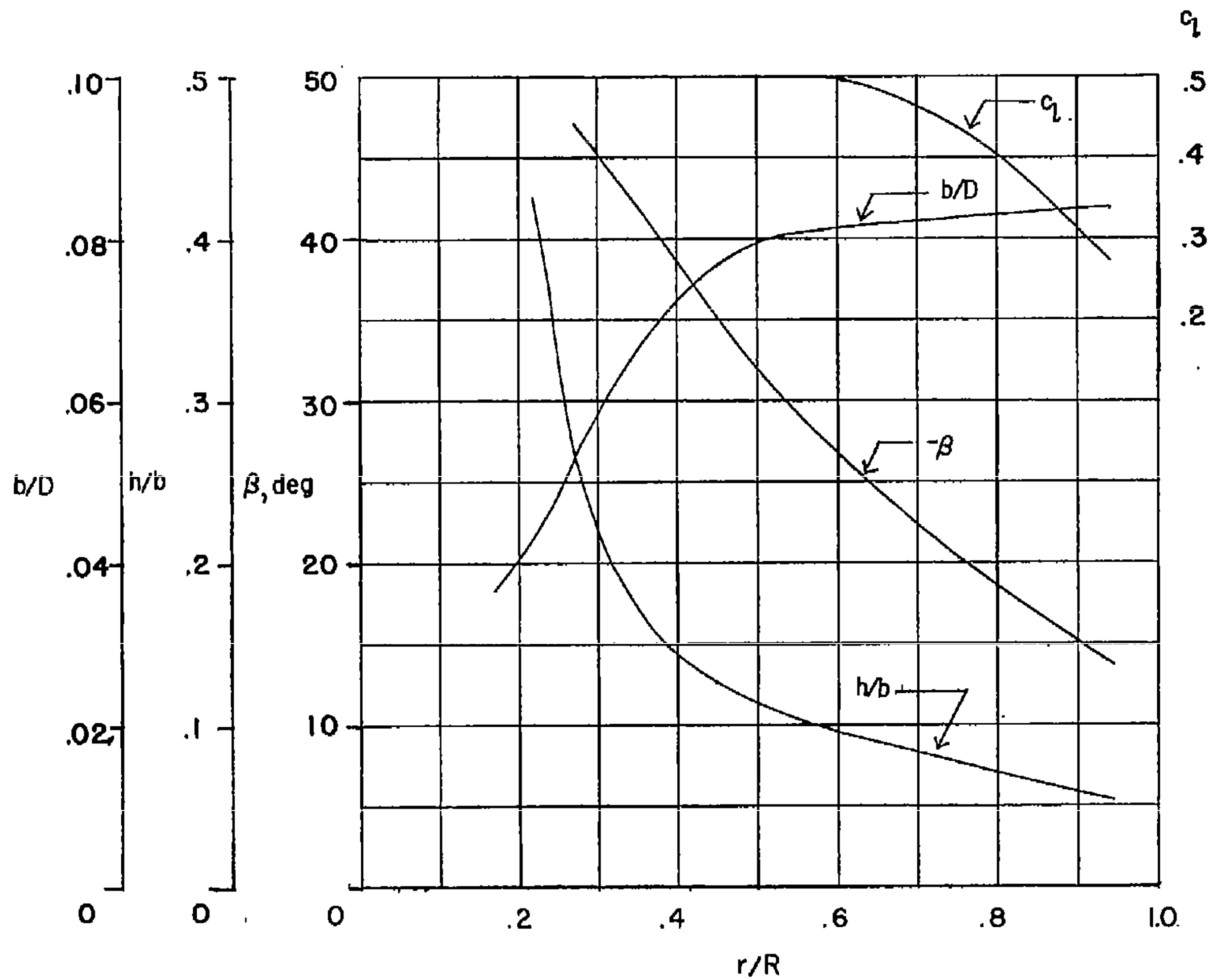
(b) Rectangular-blade plan form. L-85543.1

Figure 1.- Concluded.



(a) Tapered-blade plan form (present test).

Figure 2.- Characteristics of the propeller blades tested.



(b) Rectangular-blade plan form (ref. 1 test).

Figure 2.- Concluded.

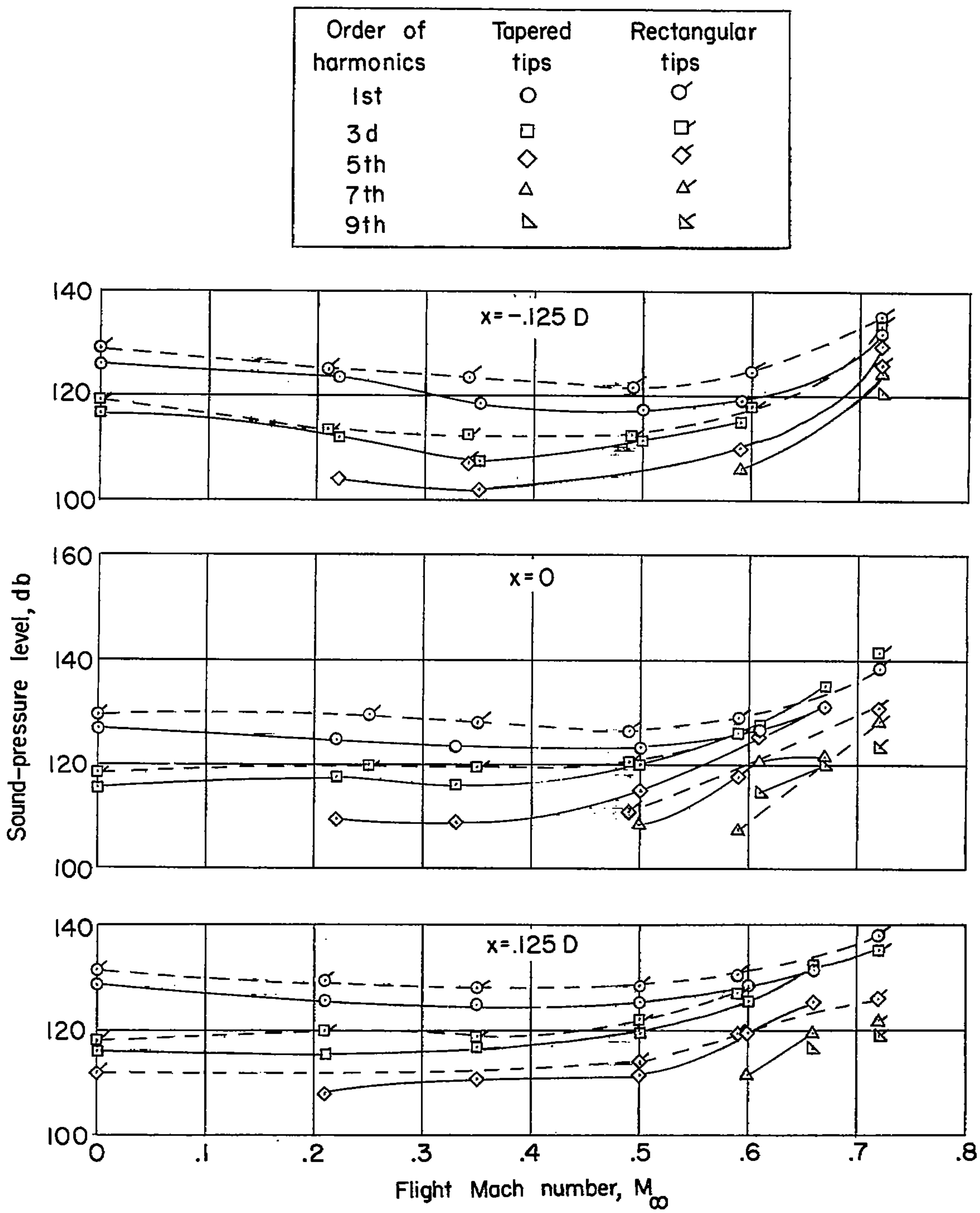


Figure 3.- Variation of propeller noise harmonic content with flight Mach number. $N \approx 2{,}700$ rpm; $P \approx 1{,}000$ hp; $y = 0.655D$.

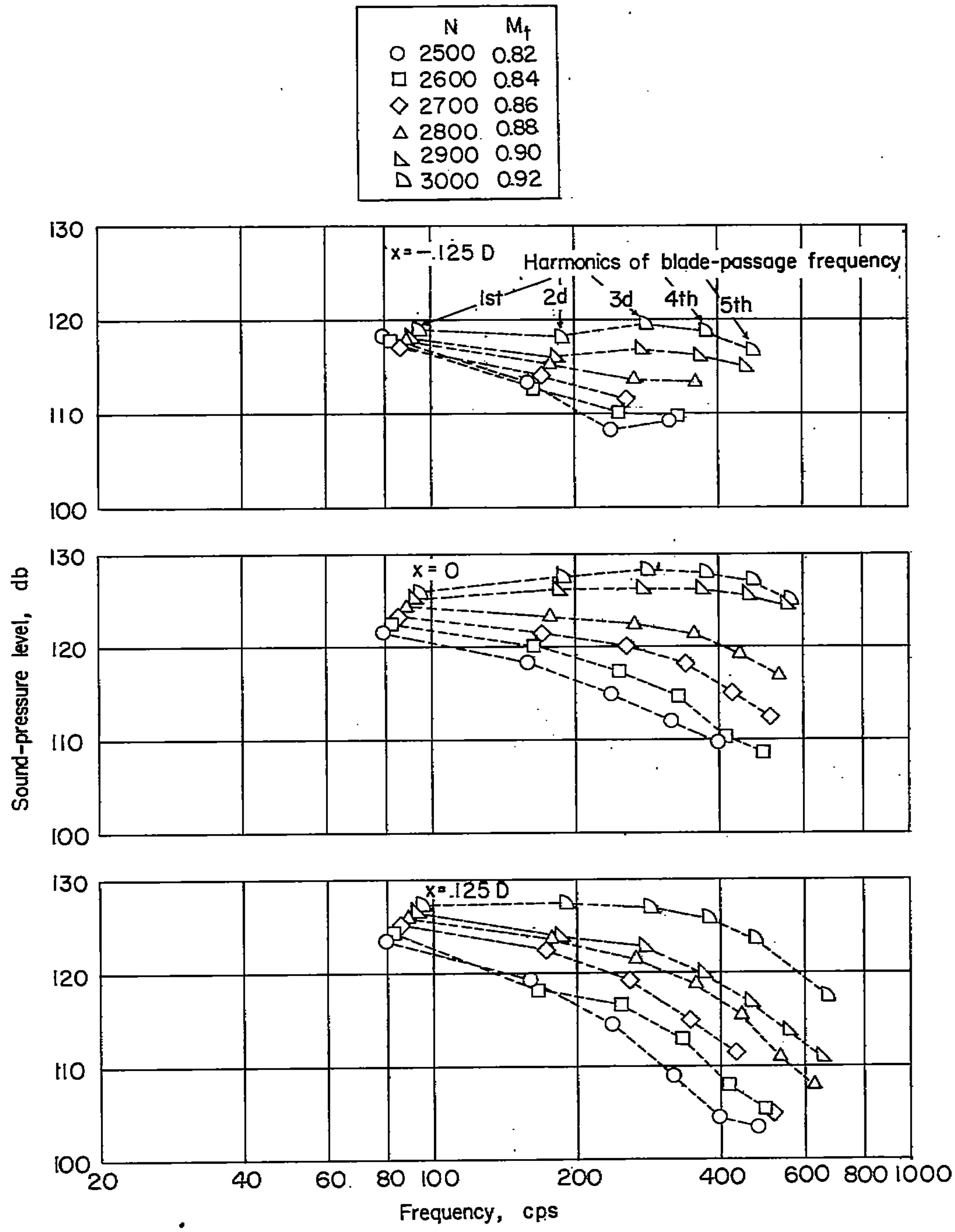
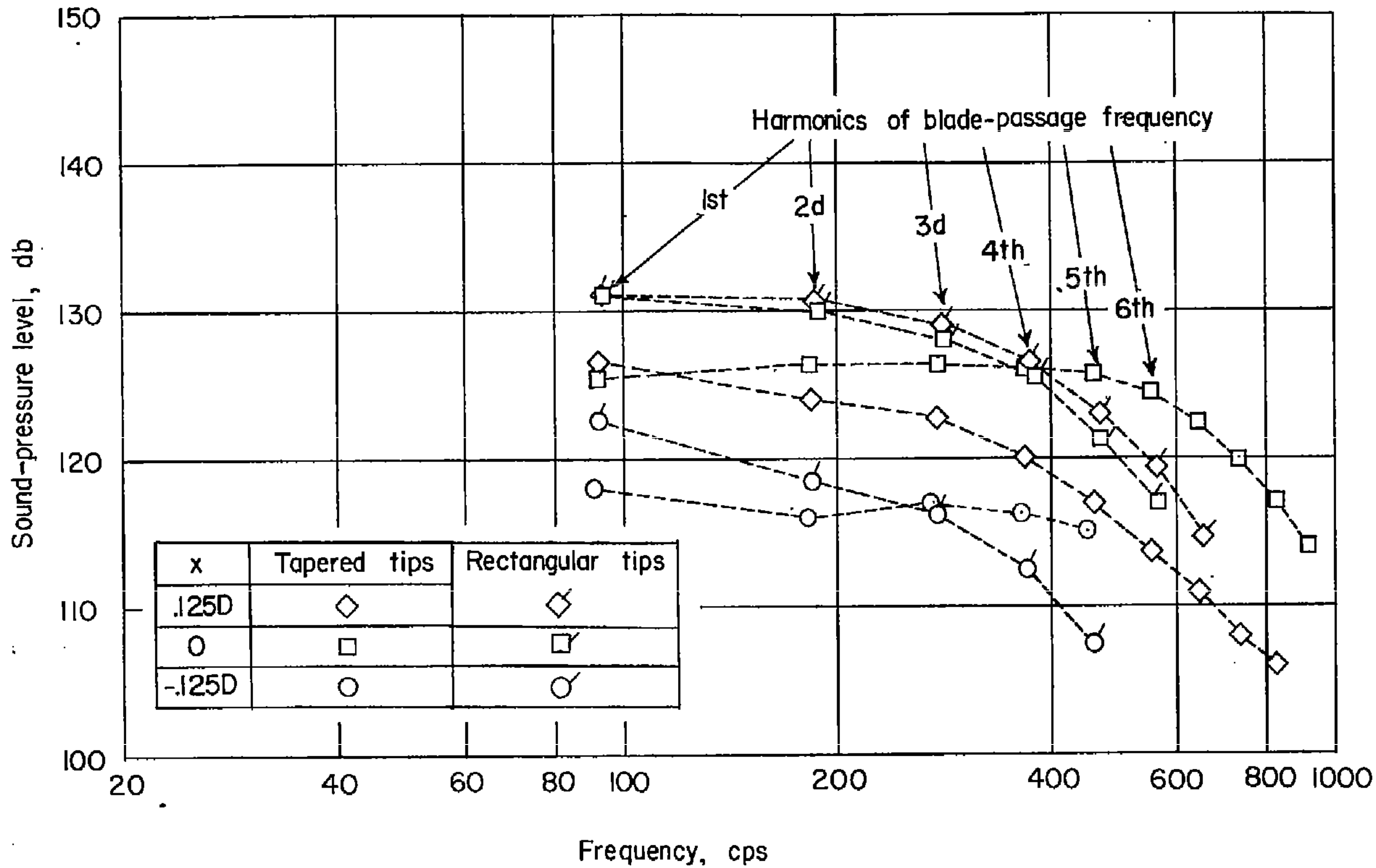
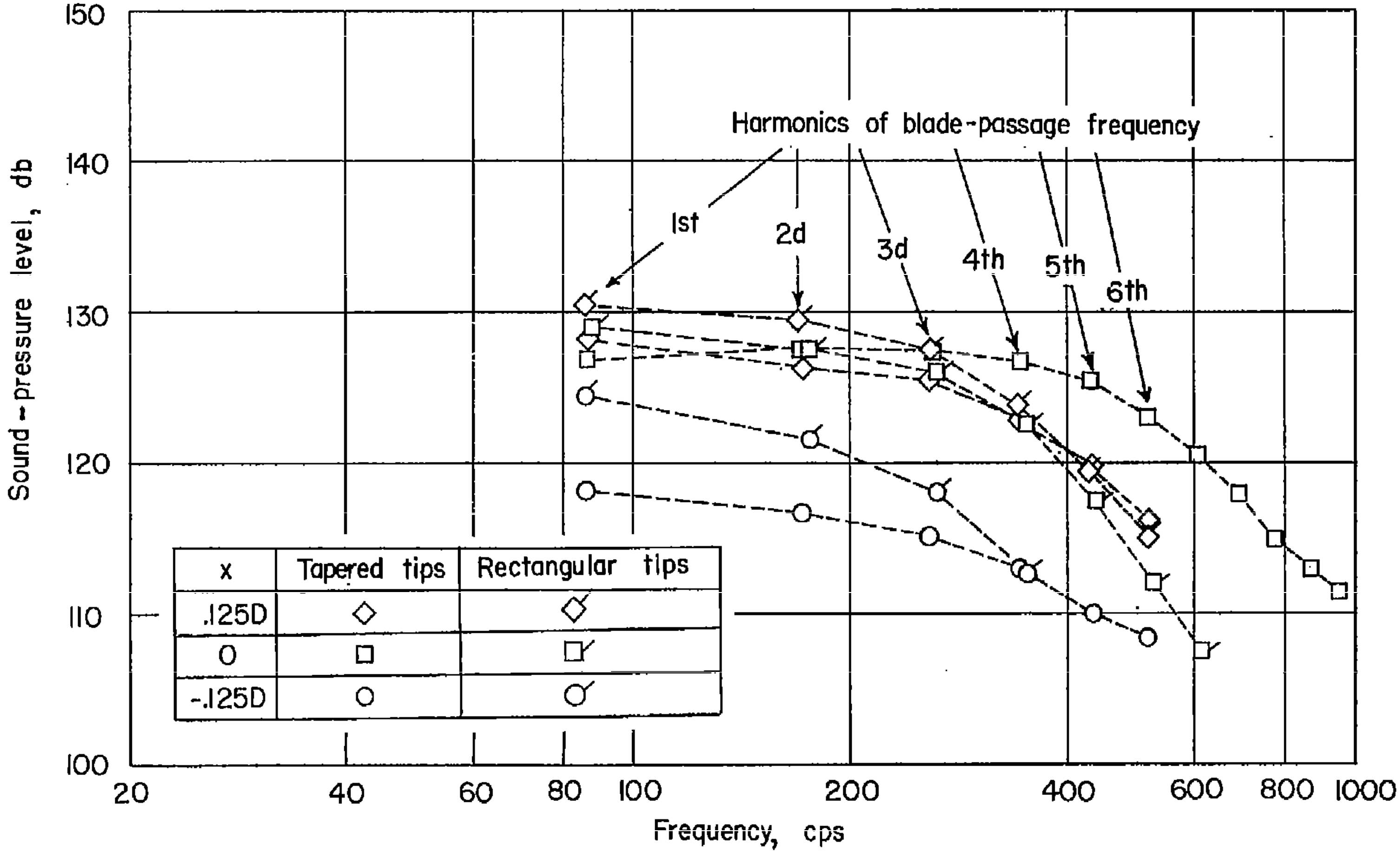


Figure 4.- Variation of sound-pressure levels with engine speed for the tapered-blade propeller. Blade-passage harmonics are connected with dashed lines for identification purposes only. $M_\infty \approx 0.5$; $P \approx 1{,}000$ hp; $y = 0.655D$.



(a) $M_\infty \approx 0.5$; $N \approx 2{,}900$ rpm; $P \approx 1{,}000$ hp; $y = 0.655D$.

Figure 5.- Variation of sound-pressure levels with axial microphone location. Blade-passage harmonics are connected with dashed lines for identification only.



(b) $M_\infty \approx 0.6$; $N \approx 2{,}700$ rpm; $P \approx 1{,}000$ hp; $y = 0.655D$.

Figure 5.- Concluded.

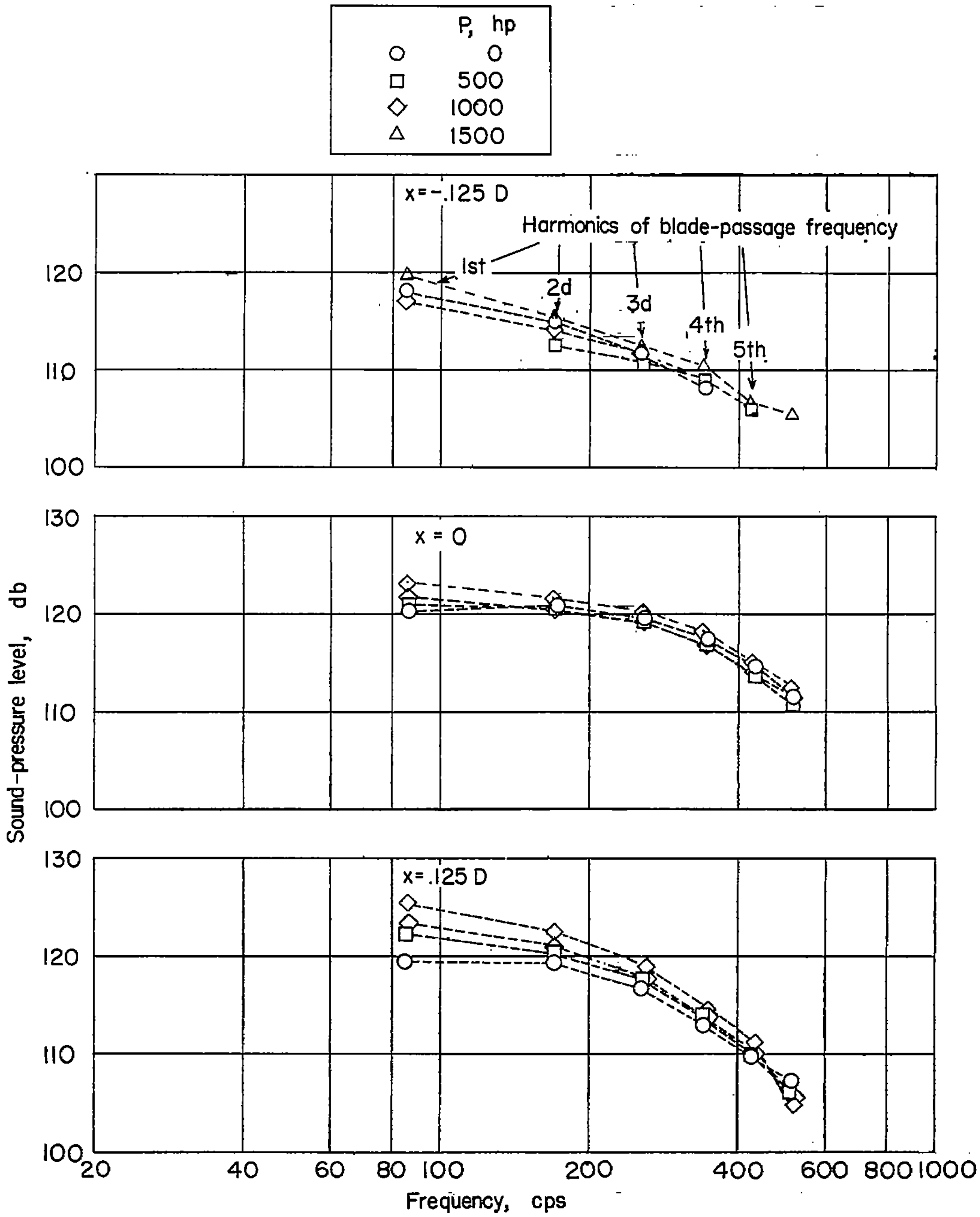


Figure 6.- Variation of sound-pressure levels with engine power for the tapered-blade propeller. Blade-passage harmonics are connected with dashed lines for identification purposes only. $M_\infty \approx 0.5$; $N \approx 2{,}700$ rpm; $y = 0.655D$.